

SOME RETINAL RESPONSE PATTERNS IN PERCEPTION  
OF APPARENT MOVEMENT

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## CHAPTER I

### Introduction

The question of identity between perceptions of real and apparent movement is one of the significant problems of visual perception. Real movement (RM) involves observation of objects under conditions of continuous physical displacement in the visual field. Apparent movement (Beta type) (AM), on the other hand, involves the alternate presentation of two or more stationary objects under conditions which usually lead to a report of perception of movement. Physically, the two events are highly dissimilar. Psychologically, however, perceptions of these two kinds of events may be indistinguishable.

Dimmick and Scahill (8), among others, have demonstrated this phenomenal identity of perception. They presented observers first with an actually moving black horizontal line, and second with two stationary black horizontal lines alternately presented. In the first case, the line appeared as stationary for a period of 30 msec, moved downward 1 inch during a 90 msec interval, remained stationary for 30 msec, and then disappeared. In the second case, one stationary line appeared for a 30 msec interval then disappeared. Ninety msec later the second stationary line appeared 1 inch below the first for a period of 30 msec, and then disappeared. All observers gave reports of movement with both types of stimuli. No observer noted that there were two different kinds of stimuli.

Observations of this type have led some investigators to postulate an identity of mechanisms, or processes, subserving these two events. Wertheimer (in Helson, 18) early took the position that if there is no difference in the movement perceived from two stationary slits of light exposed in rapid succession from that from a single moving object, then physiological processes underlying them must be identical. Dimmick (8) took a similar position, particularly after his observers reported a "gray flash" phenomenon which filled in the interval between stimuli and assured a certain continuity of movement. J. F. Brown (6) has concluded that "The thesis that the underlying physiological processes for both real and apparent movement are of the same nature is essentially correct and hence the explanation of one fact will also bring the explanation of the other" (p. 256). J. J. Gibson (11) has stated that "the distinction between 'real' and 'apparent' movement is unfortunate and has interfered with the search for the essential conditions." His position is that perception is a function of the total retinal field, and that the specific stimulus for motion may be order (p. 310). Hansel (14) also accepts the identity of percept and process, as apparently does Graham (13), who states ". . . it may be useful to note that, under ideal circumstances, real movement may be thought of as approximating apparent movement . . ." (p. 1024). Finally, Forgas (9), writing in 1963, treats these two events as aspects of a "unitary phenomenon" (p. 224).

Unfortunately, despite the obvious interest displayed in the relations between real and apparent movement, as well as the often-stated conviction that an adequate theory of visual perception must

explain both these events, there has been almost no empirical work reported in the literature which addresses itself to direct comparisons of these perceptions beyond the level of phenomenal report.

However, P. A. Kolers (22) has demonstrated the fruitfulness of such direct comparison. He addresses his study to the question of the ". . . extent of similarity in processing of the two perceptions, [which, he says] . . . seems never to have been tested directly" (p. 192). His investigation deals primarily with the interspace between the onset and offset of stimulation in the case of both real and apparent movement. This is one point of great physical difference between the two phenomena. It is also, as Kolers points out, implicit in the statements of those who argue for identity of percept and process, that " . . . stimulation by a physically moving image of the retinal regions between the termini [of stimulation] is regarded as irrelevant for a perception of movement" (p. 192).

Following recent research on visual masking (3, 10, 23, 24), Luria and Kolers (24) demonstrated that if a small luminous line of light (a target) is flashed on a screen on the path of movement of another projected line of light, the probability of reporting the presence of the target will decrease providing the intensity of the projected light is increased, or if the target is flashed closer to the projected line (p. 193).

Kolers (22) then investigated the effect of flashing a similar target light in the perceived path of a line in apparent movement. He found that the "position" of the target in the path of movement did not affect its visibility threshold as was true of the target



in the case of real movement. Further, he found that the perceived path of apparent movement became curved in depth as though to avoid the target light in its path. In another part of his investigation, Kolers found that, in the case of apparent movement, a stimulus form, ". . . masked to the point of invisibility at the origin of movement, was still reported to be seen in movement" (p. 205). Thus, only the physical presence of the stimulus, not a perception of it, is required for a report of apparent movement.

Kolers concludes from his study that real and apparent movement are fundamentally different phenomena despite their phenomenological identity, that the perceived unity may be ". . . an end product organized from a number of separable operations, occurring in different places, rather than an isomorphic representation of the physical field based on strict retino-topical projection" (p. 204).

#### Development of the Problem

The present investigation represents an attempt to extend the search for similarities and/or differences between these phenomena at the level of retinal response. The rationale for such a study comes from a need to make explorations at all levels of input and processing if we are to come to a full understanding of the nature of these perceptions.

It has been fairly well established in a number of studies (2, 21, 27, 30, 31), despite some difficulties attending response specification (c. f. Graham, 13), that some parts of the retina are less responsive to real movement stimuli than are others. The

general finding has been that, in parafoveal areas, movement acuity becomes poorer as successively more peripheral areas, beyond approximately  $20^{\circ}$ , are stimulated. This finding appears to hold for both scotopic and photopic receptor processes although there are wide individual differences at scotopic levels of vision (30). The same general finding has been made in the case of other measures of visual acuity, and is held to be a function of a peripheral decline in the number of receptor cells (21). It thus appears that the ability to discriminate real movement is primarily determined by the gross amount of information that is taken in by the organism's perceiving system.

Contrary to these findings, there is some evidence on hand which suggests that such is not the case for perceptions of apparent movement. Dethearage (7) has noted some differential retinal sensitivity to apparent movement stimuli. He states that apparent movement occurs more readily in peripheral vision (p. 263). He has suggested that different retinal areas may have different basal speeds for apparent movement, but he has made no systematic study of this observation. Sweet (29), in a study of temporal discrimination of light stimuli at different retinal locations, found that the light-adapted retinal periphery was capable of a "highly precise" report of the apparent movement of two adjacent light flashes when it could not make a temporal discrimination with regard to them (p. 198). This, however, was true only under photopic viewing conditions. Ammons and Weitz (4) have reported that stimulation of the retinal periphery resulted in greatest report of beta apparent movement when

compared with central areas; however, no extensive variation of locus of peripheral stimulation was made. Rusnak (26), in a study of diplopic viewing conditions and other factors, found some irregular changes in mean duration of perception of apparent movement at several parafoveal loci in both horizontal and vertical planes. In general, his results tend to support an hypothesis of no reduction in perception as stimulation becomes more peripheral. However, it is not possible to specify the retinal loci of stimulation in this case. Hilarides (19), in a study of apparent movement under diplopic viewing conditions and variations in flash rate, found greater mean and total durations of apparent movement perception under heterophoric viewing than under orthophoric viewing conditions at two flash rates. A conclusion suggested that the increase was due to a more peripheral locus of stimulation in the first condition, though locus was not specified.

The foregoing evidence suggests that peripheral areas of the retina are not less responsive to apparent movement stimuli than are more central areas, as is the case with real movement stimuli. In fact, it is possible to argue from the above evidence that peripheral stimulation produces "better" apparent movement than does more central stimulation. Substantiation of such findings should tend to support those who argue, as does Kolers, that there are indeed basic differences between perceptions of real and apparent movement.

This investigation also included a study of the possible interaction between locus of stimulation and flash rate of presentation of stimuli. Flash rate has been found to be a significant variable in perception of apparent movement under many different conditions

of viewing (5,15,19,20,28,33). But, with the exception of the Hilarides and Rusnak studies, viewing has been generally confined to an area within  $2-3^{\circ}$  of the center of the fovea.

From the above background the following hypotheses were formulated for the purposes of this investigation:

1. One's ability to perceive apparent movement is not primarily a function of the amount of information put into the perceptual system, but rather depends only upon the presence or absence of stimulation. Therefore, even though stimulation becomes more peripheral and the number of receptor elements decreases, perception of apparent movement, measured by total duration of report of movement, will not change.
2. Flash rate of presentation of apparent movement stimuli is a primary determinant of perception of that phenomenon and is largely independent of other variables. Therefore, variation of locus of stimulation will have no effect upon response to variations in flash rate.

Two primary variables were selected, flash rate and retinal locus of stimulation. The design conforms to Hayes' (17) description of a two-way fixed effects with replications model. Analyses

of variance of the dependent variable, total duration of report of perception of movement, were made using his procedures.

## CHAPTER II

### Apparatus

The light stimuli were presented in the fronto-parallel plane. They were produced by the output of two glow modulator tubes mounted on a vertical panel located 109 cm from the observer. The panel could be rotated so that the lights appeared either vertical or horizontal to the observer.

An electronic pulse generator, described previously (28), produces a square wave (5 microsec rise time). A multivibrator device for switching allows a wide range of exposure times. The generator output was calibrated in pulses per second (pps). The output of the generator was fed alternately to each of two 1130B Sylvania flash tubes. The light output of these tubes, passed through a square of diffusing glass, became stimuli for the production of AM. Mean intensity of the lights at the viewing apertures was 1.75 ftL for the left, and 2.03 ftL for the righthand light. This discrepancy was a function of the tube circuitry and has no relevance for perception of apparent movement (28). The viewing apertures provided round patches of white light 2.5 cm in diameter, separated 6.5 cm center to center. The lights subtended a visual angle of  $4^{\circ}8'$  on the retina.

A headrest was mounted on a vertical pivot over a dial calibrated from  $0^{\circ}$  to  $40^{\circ}$  of horizontal angle at the observer's position.

A pointer mounted on the headrest provided control of rotation for the required degree of peripheral stimulation. The headrest was adjustable vertically to collimate the observer's eye to the beam axis. A fixation light, mounted at eye level, also served to stabilize direction of sight. This light, emitted from a 6-volt flashlight bulb, passed through a 1 mm hole. At the 0° locus, the fixation light was switched off and the observer fixated on the right-hand stimulus light. A medical eye-patch was used to occlude vision in the left eye.

Records of the dependent variable, durations of perceptions of AM, for each one minute observation period were made with two channels of a Gerbrands recorder. One channel was activated by the observer, the other by the experimenter who recorded the observation period. Telegraph keys served for both operations.

#### Procedure

In this study, nine loci of retinal stimulation, described in degrees of arc from the center of the fovea, were presented to the observers. The values were 10°, 20°, 30°, and 40° in the horizontal plane, and 10° and 20° both up and down in the vertical plane. A central locus (0°), with one stimulus light positioned in the fovea, was a treatment condition, and also served as a control. Stimulus lights were horizontally positioned in the horizontal plane, and vertically in the vertical plane to preserve axial symmetry in AM stimulation.

The horizontal locus values are near those used by Klein (21)

in his study of real movement. Results from this part of the study provide a basis for direct comparison between perceptions of real and apparent movement. To make other conditions comparable to the Klein study, stimulation was monocular with the right eye, and illuminance was at photopic levels of visibility.

A sample of 10 male observers, with normal, or corrected to normal, vision was employed in this study. Each observer appeared twice in the experimental situation. On his first appearance, each observer was seated at the viewing tunnel and the general purpose of the experiment was explained. Then the stimulus lights were switched on and the rate of presentation was varied over a range from succession to simultaneity until each reported perception of movement independently of any instruction about what he should see.

After each had reported the appearance of one light moving, jumping, or bouncing, etc., back and forth, he was given a few minutes additional experience at several rates until he had demonstrated his perception of the criterion at least three times. He was also instructed in head positioning, use of the telegraph key, and in fixing on the fixation light. He was then excused until the following day.

On his second appearance, each observer was given a warm up period of about three minutes in which he re-identified the criterion and then had any questions about the procedure or the experiment answered by the experimenter.

Each observer was then given those final instructions:



Please sit as still as possible during the observation period. Look directly at the fixation light, but at the same time pay attention to the two flashing lights. Any time you see them fuse into the appearance of one light moving back and forth or up and down, press down on the key. Hold it down as long as you see one light moving. Any time you do not see one light moving back and forth or up and down, let up on the key. Be conservative in your judgments, if you are not sure you see one light moving do not press the key.

Following this, each observer was presented with a randomized sequence of the 36 treatments of one minute duration. Each treatment condition included one of the nine locus values and one of the four rate values; horizontal and vertical positions were mixed in the sequence.

The experiment took place in a quiet, light-tight room. By switching the pulse generator so that both stimulus lights were present between observation periods, the observer's light adaptation was kept constant.

## CHAPTER III

### Results

The design of this study included four rate variables and nine locus variables. However, the use of only two loci in the vertical directions necessitated treating the latter part of the data separately. In all cases the dependent variable was total duration of Beta AM perception within each observation period of one minute duration.

First, an analysis of variance of the data from the foveal locus ( $0^{\circ}$ ) nasally to  $40^{\circ}$  in the horizontal plane was made. The raw data were arranged as a 4 X 5 fixed-effects model using Hayes' (17) description. The .01 level of significance was chosen as an appropriate point at which to reject an hypothesis of no treatment effects.

The summary in Table 1 shows that both rate and locus were significant variables in the perception of Beta AM. The interaction F-ratio was less than 1.0, indicating that the main effects are independent of each other. Additionally, Bartlett's test indicated that the variances are homogeneous.

Locus.--Tests for trend were carried out at each rate of presentation. Linear components account for the major amount of variation due to locus, but they reached significance only at rate 5.0 pps (Table 2).

Table 1

Analysis of Variance for Main Effects and Interaction

Source	SS	df	MS	F
Rate	9,877.8	3	3,292.6	8.9**
Locus	5,577.3	4	1,384.3	3.8##
Interaction	3,788.6	12	315.7	-
Error	66,392.1	180	368.8	
Total	85,635.8			

\*\*F<sub>.01</sub>(3,180) = 3.9##F<sub>.01</sub>(4,180) = 3.4

Table 2

Tests for Trend  
(Values > 1.0)

Rate	Linear	Quadratic	Cubic
0.5 pps	-	1.3	2.5
3.0 pps	2.5	1.2	-
5.0 pps	8.0*	-	4.0
6.0 pps	3.0	-	-

\*F<sub>.01</sub>(1,45) = 7.3

In order to extract specific information regarding the location and direction of significant effects, it is necessary to go beyond the overall analysis of variance. A procedure devised by Dunnett in Winer (32, p. 89) affords a means of comparing various treatments with a control (here the peripheral loci of stimulation with the 0° locus)

by giving a single critical value for all relevant decisions. (Additionally, the overall pattern of response to rate at each peripheral locus was compared to that at the perifoveal locus.) Table 3 summarizes these results and shows that neither the overall pattern of response, nor response to any single rate at any single locus varies by a significant amount from that of the control. The response variability which led to the finding of a significant overall F-ratio (Table 1) occurred between the 20° and 30° loci.

Table 3  
Comparisons of Perifoveal with Peripheral  
Stimulation at Each Rate of Presentation:  
Fisher's t-test, Two-tailed

Rate	<u>t</u> :0°-10°	<u>t</u> :0°-20°	<u>t</u> :0°-30°	<u>t</u> :0°-40°	C.V. (.01)
All rates	-	-	1.08	-	+2.77
0.5 pps	-	-	1.21	-	+2.92
3.0 pps	-	-	-	1.36	+2.92
5.0 pps	1.55	-	1.47	1.56	+2.92
6.0 pps	-	1.47	1.47	1.20	+2.92

The data for loci in the vertical plane were treated differently. A graph of the cell means (see Figure 1) suggested a radially symmetrical pattern of response to rate at 10° and 20° with a sharp rise at 10°. Fisher's t-test was used to assess the importance of this increase over perifoveal response at rates 3.0 and 5.0 pps. The summary in Table 4 indicates no significant difference from

response at  $0^{\circ}$ , although the increase is similar to that observed by Ammons and Weitz (4).

Table 4  
Comparison of Perifoveal and Vertical Peripheral  
Stimulation at Two Rates; Fisher's  $t$ -test

Rate	Loci	$t$	C.V. (.01)
3.0 pps	$0^{\circ}$ - $10^{\circ}$	1.38	2.42
5.0 pps	$0^{\circ}$ - $10^{\circ}$	1.97	2.42

Rate.--Figure 2 shows the response to rate at the five loci. The general pattern is similar to that found in a number of previous studies made using this equipment. A summary by Bowen (5) shows that response to rates at or near 3.0 pps is high compared with that to rates below approximately 1.0 pps and above approximately 4.5 pps. These values encompass a range of optimal movement. An earlier study by Hart (15) defined lower and upper thresholds by means of the 50 percent response criterion for 1 minute observation periods. His values were  $1.71 \pm 0.12$  pps for the lower threshold, and  $5.26 \pm 0.12$  pps for the upper threshold.

For this study cell means of the rate variable in the  $4 \times 5$  matrix were compared with each other using the Newman-Keuls procedure. Winer describes this as a modified  $q$  statistic which is ". . . particularly useful in probing the nature of differences between treatment means following a significant overall  $F$ " (32, p. 77). The procedure establishes separate critical values for each ordered-pair comparison while at the same time maintaining a single level of significance (.01).



Figure 1. A Comparison of Durations of Response to Rate at 10° and 20°; Horizontal and Vertical

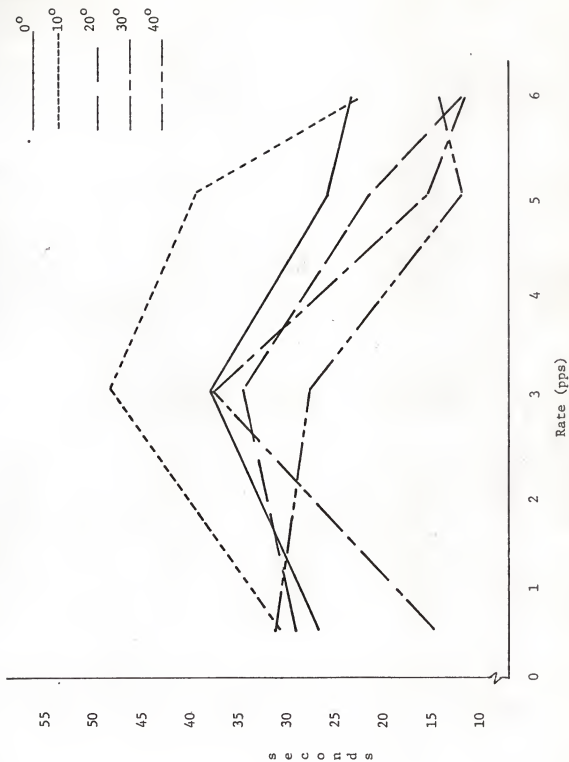


Figure 2. Total Durations of Response to Rate at Each Locus

Table 5 and Figure 2 show these comparisons. Total duration of response at rate 3.0 pps is significantly higher than total duration of response at 5.0 or 6.0 pps for every locus but one ( $10^{\circ}$ ) where response to 5.0 pps is not significantly lower. Total duration of response to rate 0.5 pps is significantly lower than to 3.0 pps at both  $10^{\circ}$  and  $30^{\circ}$ , and lower, though not significantly so, at  $0^{\circ}$  and  $20^{\circ}$ . On the other hand, total duration of response to 0.5 pps is actually higher than response to 3.0 pps at  $40^{\circ}$ . Thus, while the present results correspond well with Bowen's general findings, they give only limited support to Hart's threshold values.

A comparison was also made between total durations of response and mean durations of response. There is in the literature (5) some question as to which is a more appropriate measure of the response to perceptions of Beta AM. Figure 3 shows that, over the range of rate values investigated here, response curves to both total and mean durations are similar in shape. Thus, both measures appear to carry essentially the same kind of information.



Table 5

Differences in Mean Durations (Seconds) of Response  
to Rate at Each Locus, Ordered by Magnitude of Cell Mean  
(Only Significant Values Shown)

<u>Locus 0°</u>				
	6.0	5.0	0.5	3.0
6.0	-			14.6
5.0		-		12.0
0.5			-	
<u>Locus 10°</u>				
	6.0	0.5	5.0	3.0
6.0	-		16.3	20.6
0.5		-		12.7
5.0			-	
<u>Locus 20°</u>				
	6.0	5.0	0.5	3.0
6.0	-		17.2	22.5
5.0		-		13.0
0.5			-	
<u>Locus 30°</u>				
	6.0	5.0	0.5	3.0
6.0	-			25.4
5.0		-		23.9
0.5			-	22.4
<u>Locus 40°</u>				
	5.0	6.0	3.0	0.5
5.0	-		15.2	18.9
6.0		-	13.3	17.0
3.0			-	
Critical Values of $\alpha$ (.01)	-	9.5	11.2	11.9

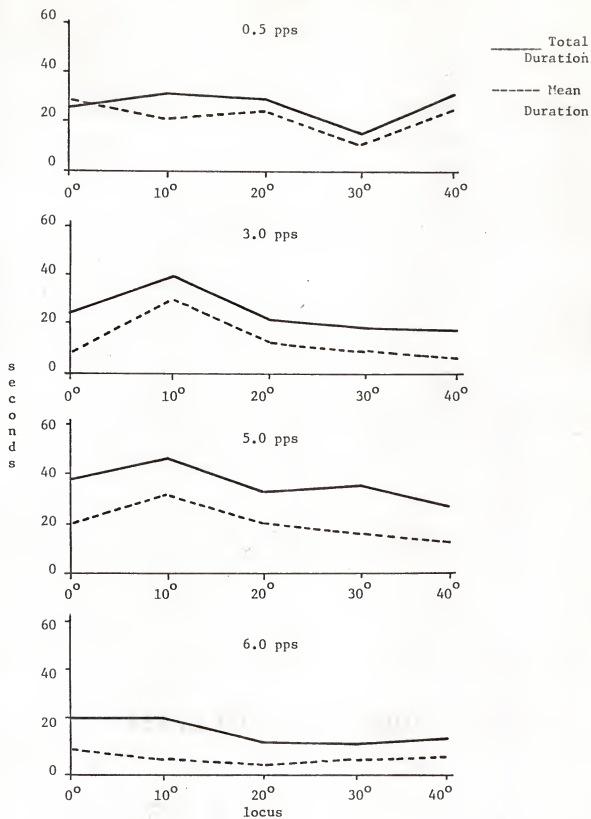


Figure 3. A comparison of Mean and Total Durations of Response to AM Stimuli; Five Retinal Loci, Four Presentation Rates.

## CHAPTER IV

### Discussion

The first hypothesis was developed from a study of the effects of a change in locus of stimulation on AM perception (19) in which there appeared to be some difference in response duration when locus was changed. The results here indicate that, within the temporal range used, the retina may be said to function as a homogeneous field with respect to AM stimuli. The patterns of response at several horizontal loci in the nasal periphery are not significantly different from that at a central locus which included the fovea. Additionally, the limited explorations both upward and downward in a vertical plane at  $10^{\circ}$  and  $20^{\circ}$  gave results essentially the same as those obtained at  $10^{\circ}$  and  $20^{\circ}$  horizontally. The possibility that similar findings would be made in any plane at any locus may be considered for further research.

The second hypothesis was confirmed in that the rate factor had the same effect on response durations at both peripheral and central loci. Response durations for different rates of stimulation did not show a significant difference in any peripheral locus when compared to the central locus.

The present data, then, do not lend support to the conclusions of Wertheimer, Brown, and others that AM and RM are identical phenomena, subsumed by the same physiological mechanisms. Studies

of RM thresholds in central and peripheral regions of the retina provide a good point at which to explore this argument. Such studies have been made by a number of individuals (2, 21, 27, 30, 31). Despite differences in their experimental designs and criterion measures, their conclusions were consistently similar in nature; as stimulation becomes more peripheral, the threshold for RM perception becomes higher. Klein (21), for example, has concluded that "Sensitivity to [real] motion under photopic illumination is definitely not as high in the peripheral regions [of the retina] as it is near the fovea. This tendency is remarkably consistent from subject to subject" (p. 55). The findings for RM suggest that the threshold is in part a function of the amount of information received per unit time and thus dependent upon retinal structure, although Klein (21, p. 213) has produced evidence indicating that changes in RM thresholds do not closely correspond to changes in the gross number of receptors in the retinal periphery. On the other hand, it has not yet been shown that RM thresholds do not vary with the distribution of neural structures in the retina which respond only to movement.

The findings for AM perception gathered in this study are different. The pattern of response durations to different rates of AM stimulation (Figure 2) does not change significantly in the nasal periphery from that in the central locus. Rates of stimulation near the lower (1.71 pps) and upper (5.26 pps) thresholds defined by Hart (15), as well as those in between, are responded to in the periphery the same as in the foveal area despite the known structural

and functional differences in receptor elements in these regions.

The findings suggest at least two interpretations of the comparative data. One is that the concept of movement threshold must be applied differently to the observations of AM. The other is that AM thresholds, and thus the organization of AM perceptions, are mediated by structures and/or processes different from those dealing with RM. Neither of these interpretations supports the case for identity, and, it is a conclusion of this study that the theory of identity between AM and RM is not tenable in the light of this evidence.

The facts of this study, taken by themselves, give some support to explanations of AM perception which embody hypotheses of cortical excitability cycles, physiological scanning processes, and the like. Aarons (1) has reviewed this field briefly, and Harter (16) has recently made a critical evaluation of these hypotheses. There is some evidence that "optimal" temporal spacing of the AM stimuli corresponds in some way to cortically produced physio-electrical discharges such as, for example, the Alpha rhythm. However, this work is still in a crude state due in part to the complexity of the physiological matrix as well as to the relatively insensitive equipment in use.

There is little work reported in the literature which relates directly to the findings of this study, thus, there is a need for replications. Present evidence is found to deal mainly with the unexpected but consistent increase in response durations to AM stimuli at the  $10^{\circ}$  locus. Deathearage (7) has reported more frequent responses to AM stimuli (stroboscopic) at peripheral loci than at a foveal locus.

although neither stimulation rates nor loci were specified. His suggestion that different retinal areas may have different thresholds (basal speeds) is not supported by the present results at other than the  $10^{\circ}$  locus. Both Rusnak (26) and Hilarides (19) have reported that a condition of induced heterophoria, which results in unilateral stimulation of the retinal periphery, did not inhibit perception of AM at rates of 2.7 pps and at 3.0 and 5.0 pps. Rusnak used eight different conditions of heterophoria, and possibly eight different peripheral retinal loci in both vertical and horizontal directions. Degree of dysphoria did not significantly affect mean perception of AM at the 2.7 pps rate. Hilarides compared one condition of heterophoria with foveal stimulation at two rates, 3.0 and 5.0 pps. Mean durations of response were higher at both rates of stimulation in the heterophoric condition. Total durations were also higher at both rates, and, at the 5.0 pps rate, reached a significant level ( $p < .05$ ) when compared to the response with foveal fixation. It was concluded that locus was effective in increasing the response duration.

There are, however, some important design differences between these two studies (26, 19) and the present one which may affect the comparability of the results from them. In the studies just summarized, stimulation was binocular, with the induced unocular displacement in the left eye. Stimuli were line circles instead of circular patches. Also, in neither of these earlier studies was it possible to clearly specify the locus of peripheral stimulation, although in the Hilarides study (19), the induced heterophoria may have shifted

the locus of stimulation as much as  $10^{\circ}$  peripherally from the fovea.

Finally, Ammons and Weitz (4), using monocular stimulation and a  $5^{\circ}$  separation between stimuli at a rate of approximately 1.0 pps, reported facilitation of response to AM stimuli at about  $10^{\circ}$  in the horizontal periphery. This appears very similar to what was found here.

Now, while the facilitation of response observed in this study at  $10^{\circ}$  and  $20^{\circ}$  was not so great that it could not be safely attributed to chance, the consistent accumulation of similar findings in other studies seems to require that it be treated more seriously. A possibly related phenomenon has been reported by Klein (21), Warden and Brown (30), Lit in Gordon, (12), and others in studies of real movement thresholds. It is noted that under scotopic viewing conditions there is a drop in threshold as stimulation proceeds outward from the fovea to a point approximately  $10^{\circ}$  in the horizontal periphery. From here outward the threshold rises steadily. Since there is no such drop in threshold under photopic viewing conditions, it would appear that the phenomenon may be related to a concentration of rod receptors at the  $10^{\circ}$  locus. However, Østerberg (25) reported an even higher concentration of rods at  $20^{\circ}$  nasally. This anatomical density of rods is not paralleled by a further drop in RM threshold or by increased durations of response of AM perceptions as stimulation proceeds in that direction.

The findings in the case of both RM thresholds under scotopic viewing conditions and AM perceptions in the present study tend to suggest some duplex response effect. Yet the evidence does not make

a good fit. An explanation in terms of duplex theory would seem to require a higher concentration of rod receptors at  $10^{\circ}$  peripherally than at  $20^{\circ}$  as Østerberg has reported. Additionally, since the AM data were gathered under conditions of low photopic viewing conditions, there is some question of a rod response independent of cone activity. Finally, the present results show patterns of response to different rates of presentation of stimuli which are quite similar at every locus tested. Unless one argues that rod function is completely suppressed under photopic viewing conditions, this evidence tends to argue against the possibility of a difference in response dependent upon type of structure. Thus, further evaluation of the duplex theory in this connection must await a more detailed investigation than was made here.

#### Summary

The perception of objects in apparent movement is, under some circumstances, indistinguishable from the perception of similar objects in real movement. This fact appears to have led some investigators to the conclusion that these two phenomena are therefore identical in all respects. However, there is almost no empirical evidence in the literature which would tend to either substantiate or refute such a position.

An area of comparative study is suggested by a review of two lines of research. (1) In studies of real movement, it is consistently found that the movement threshold is higher in the retinal periphery than in or near the fovea. (2) In studies of apparent movement



there is some evidence which suggests that movement perception is facilitated by stimulating more peripheral rather than more foveal areas of the retina.

Two hypotheses were generated for the purposes of this study:

- (1) One's ability to perceive apparent movement is not primarily a function of the locus of stimulation, and thereby related to and dependent upon the number of receptors or receptor combinations at a given position. Rather the dependency is directly attributed to the presence or absence of stimulation. Therefore, even though stimulation becomes more peripheral, and the number of receptor elements decreases, perception of apparent movement as measured by the total duration of apparent movement, will not change.
- (2) Flash rate of presentation of AM stimuli is a primary determinant of perception of that phenomenon and in peripheral areas is relatively independent of certain other variables such as form, intensity, figure-ground relations, etc. Therefore, variation in the periphery, of the locus of stimulation, will have no effect on response to variations in flash rate.

A series of nine loci of retinal stimulation and four rates of presentation of stimuli were combined into a two-way fixed effects model, following Hayes' definitions and procedures for analysis of variance. A sample of ten male subjects was employed, each receiving a random series of the stimulus variables. Stimulation was monocular, in the right eye.

The results of the study tend to support both hypotheses. Total length of report of apparent movement was not significantly different at any peripheral locus than at the fovea. Total length of report of apparent movement was essentially the same at every rate of presentation for every locus of stimulation.

It was a conclusion of the study that the results cast doubt on the theory stated by Brown, Wertheimer, and others which holds apparent and real movement to be identical phenomena. The findings give some support for theories which explain apparent movement phenomena in terms of cortical excitability cycles and scanning hypotheses.

There was also found a facilitation of AM response near  $10^{\circ}$  peripherally which, while not significant, was consistent in both horizontal and vertical planes. This finding was discussed relative to a drop in real movement thresholds near the same retinal locus. Certain aspects of the duplex theory of vision were discussed relative to the findings for both RM and AM.

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#### BIOGRAPHICAL SKETCH

Robert Merritt Hilarides was born January 16, 1924, at Detroit, Michigan. In June, 1941, he was graduated from Belleville High School, Belleville, Michigan. From 1943 until 1946 he served in the United States Coast Guard. Following his discharge in 1946, he enrolled at Michigan State College. In 1950 he received the degree of Bachelor of Arts from the Department of Sociology. In 1964, after some years spent in business and in teaching, he enrolled in the Graduate School of the University of Florida. He worked as a graduate fellow and graduate assistant in the Department of Psychology until December, 1966, when he received the degree of Master of Arts. From that time to the present he has worked toward the degree of Doctor of Philosophy.

Robert Hilarides is married to the former Marjorie Ruth Livingston, and is the father of three children. He is a member of Phi Kappa Phi and the American Psychological Association.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Arts and Sciences and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

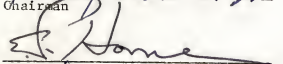
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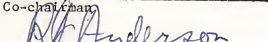
  
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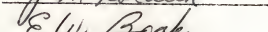
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